

# EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT THE 8038 (Revised June 1977)

# INTERSIL

The 8038 is a function generator capable of producing sine, square, triangular, sawtooth and pulse waveforms (some at the same time). Since its introduction, marketing and application engineers have been manning the phones explaining the care and feeding of the 8038 to customers worldwide. This experience has enabled us to form articulate responses to the most frequently asked questions. So, with data sheet and breadboard in hand, read on and be enlightened.

**Q1.** I want to sweep the frequency externally but can only get a range of 100 to 1. (or 50 to 1)[or 10 to 1]. Your data sheet says 1000 to 1. How much sweep range can I expect?

**A.** Let's look at what determines the output frequency. Start by examining the circuit schematic at pin 8 in the upper left hand corner. From pin 8 to pin 5 we have the emitter-base of NPN Q<sub>1</sub> and the emitter-base of PNP Q<sub>2</sub>. Since these two diode drops cancel each other (approximately) the potential at pins 8, 5 and 4 are the same. This means that the voltage from V<sub>+</sub> to pin 8 is the same as the voltage across external resistors RA and RB. This is a textbook example of a voltage across two resistors which produce two currents to charge and discharge a capacitor between two fixed voltages. This is also a linear system. If the voltage across the resistors is dropped from 10V to 1V the frequency will drop by 10:1. Changing from 1 volt to 0.1V will also change the frequency by 10:1. Therefore, by causing the voltage across the external resistors to change from say 10V to 10 mV, the frequency can be made to vary at least 1000:1. There are, however, several factors which make this large sweep range less than ideal.

**Q2.** You say I can vary the voltage on pin 8 (FM sweep input) to get this large range, yet when I short pin 8 to V<sub>+</sub> (pin 6) the ratio is only around 100:1.

**A.** This is often true. With pin 8 shorted to V<sub>+</sub>, a check on the potentials across the external RA and RB will show 100 mV or more. This is due to the VBE mismatch between Q<sub>1</sub> and Q<sub>2</sub> (also Q<sub>1</sub> and Q<sub>3</sub>) because of the geometries and current levels involved. Therefore, to get smaller voltages across these R's, pin 8 must be raised above V<sub>+</sub>.

**Q3.** How can I raise pin 8 above V<sub>+</sub> without a separate power supply?

**A.** First of all, the voltage difference need only be a few hundred millivolts so there is no danger of damaging the 8038. One way to get this higher potential is to lower the supply voltage on the 8038 and external resistors. The simplest way to do this is to include a diode in series with pin 6 and resistors RA and RB.

See Figure 1. This technique should increase the sweep range to 1000 to 1.

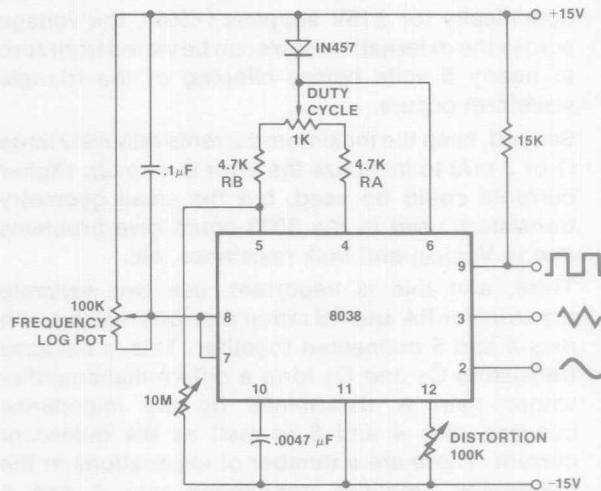


FIGURE 1. VARIABLE AUDIO OSCILLATOR, 20 Hz to 20 KHz

**Q4.** O.K., now I can get a large frequency range but I notice that the duty cycle and hence my distortion changes at the lowest frequencies.

**A.** This is caused partly by a slight difference in the VBE's of Q<sub>2</sub> and Q<sub>3</sub>. In trying to manufacture two identical transistors, it is not uncommon to get VBE differences of several millivolts or more. In the standard 8038 connection with pins 7 and 8 connected together, there are several volts across RA and RB and this small mismatch is negligible. However, in a swept mode with the voltage at pin 8 near V<sub>+</sub> and only tens of millivolts across RA and RB, the VBE mismatch causes a larger mismatch in charging currents, hence the duty cycle changes. For lowest distortion then, it is advisable to keep the minimum voltage across RA and RB around 100 millivolts. This would, of course, limit the frequency sweep range to around 100 to 1.

**Q5.** I have a similar duty cycle problem when I use high values of RA and RB. What causes this?

**A.** There is another error term which becomes important at very low charge and discharge currents. This error current is the emitter current of Q<sub>7</sub>. The application note on the 8038 gives a complete circuit description but it is sufficient to know that the current charging the capacitor is the current in RA which flows down through diode Q<sub>9</sub> and into the external C. The discharge current is the current in RB which flows down through diode Q<sub>8</sub>. Adding to the Q<sub>8</sub> current is the current of Q<sub>7</sub> which is only a few microamperes. Normally, this Q<sub>7</sub> current is negligible, but with a small current in RB, this current will cause a faster discharge than would be expected. This problem will also appear in sweep circuits when the voltage across the external resistors is small.

**Q6.** How can I get the lowest distortion over the largest frequency sweep range?

**A.** First of all, use the largest supply voltage available ( $\pm 15V$  or  $+30V$  is convenient). This will minimize VBE mismatch problems and allow a wide variation of voltage on pin 8. The potential on pin 8 may be swept from  $V_{CC}$  (and slightly higher) to  $(2/3 V_{CC} + 2V)$  where  $V_{CC}$  is the total voltage across the 8038. Specifically for  $\pm 15V$  supplies ( $+30V$ ), the voltage across the external resistors can be varied from zero to nearly 8 volts before clipping of the triangle waveform occurs.

Second, keep the maximum currents relatively large (1 or 2 mA) to minimize the error due to Q7. Higher currents could be used, but the small geometry transistors used in the 8038 could give problems due to  $V_{CE(sat)}$  and bulk resistance, etc.

Third, and this is important, use two separate resistors for RA and RB rather than one resistor with pins 4 and 5 connected together. This is because transistors Q2 and Q3 form a differential amplifier whose gain is determined by the impedance between pins 4 and 5 as well as the quiescent current. There are a number of implications in the differential amplifier connection (pin 4 and 5 shorted). The most obvious is that the gain determines the way the currents split between Q2 and Q3. Therefore, any small offset or differential voltage will cause a marked imbalance in the charge and discharge currents and hence the duty cycle. A more subtle result of this connection is the effective capacitance at pin 10. With pins 4 and 5 connected together, the "Miller effect" as well as the compound transistor connection of Q3 and Q5 can produce several hundred picofarads at pin 10 seriously limiting the highest frequency of oscillation. The effective capacitance would have to be considered important in determining what value of external C would result in a particular frequency of oscillation. The single resistor connection is fine for very simple circuits, but where performance is critical, the two separate resistors for RA and RB are recommended. Finally, trimming the various pins for lowest distortion deserves some attention. With pins 7 and 8 connected together and the pot at pin 7 and 8 externally set at its maximum, adjust the ratio of RA and RB for 50% duty cycle. Then adjust a pot on pin 12 or both pins 1 and 12 depending on minimum distortion desired. After these trims have been made, set the voltage on pin 8 for the lowest frequency of interest. The principle error here is due to the excess current of Q7 causing a shift in the duty cycle. This can be partially compensated for by bleeding a small current away from pin 5. The simplest way to do this is to connect a high value of resistance (10 to 20 m $\Omega$ ) from pin 5 to V<sub>T</sub> to bring the duty cycle back to 50%. This should result in a reasonable compromise between low distortion and large sweep range.

**Q7.** This waveform generator is a piece of junk. The triangle wave is non-linear and has large glitches when it changes slope.

**A.** You're probably having trouble keeping the constant voltage across RA and RB really constant. The pulse output on pin 9 puts a moderate load on both supplies as it switches current on and off. Changes in the supply reflect as variations in charging current, hence non-linearity. Decoupling both power supply pins to ground right at the device pins is a good idea. Also, pins 7 and 8 are susceptible to picking up switching transients (this is especially true on printed circuit boards where pins 8 and 9 run side by side). Therefore, a capacitor (.1  $\mu F$  or more) from V<sub>T</sub> to pin 8 is often advisable. In the case when the pulse output is not required, leave pin 9 open to be sure of minimizing transients.

**Q8.** What is the best supply voltage to use for lowest frequency drift with temperature?

**A.** The 8038AM, 8038AC, 8038BM and 8038BC are all temperature drift tested at  $V_{CC} = +20V$  (or  $\pm 10V$ ). A curve in the lower right hand corner of Page 4 of the data sheet indicates frequency versus temperature at other supply voltages. It is important to connect pin 7 and 8 together.

**Q9.** Why does connecting pin 7 to pin 8 give the best temperature performance?

**A.** There is a small temperature drift of the comparator thresholds in the 8038. To compensate for this, the voltage divider at pin 7 uses thin film resistors plus diffused resistors. The different temperature coefficients of these resistors causes the voltage at pins 7 and 8 to vary  $0.5 \text{ mV}/^\circ\text{C}$  to maintain overall low frequency drift at  $V_{CC} = 20V$ . At higher supply voltages e.g.,  $\pm 15V$  ( $+30V$ ), the threshold drifts are smaller compared with the total supply voltage. In this case, an externally applied constant voltage at pin 8 will give reasonably low frequency drift with temperature.

**Q10.** Your data sheet is very confusing about the phase relationship of the various waveforms.

**A.** Sorry about that! The thing to remember is that the triangle and sine wave must be in phase since one is derived from the other. A check on the way the circuit works shows that the pulse waveform on pin 9 will be high as the capacitor charges (positive slope on the triangle wave) and will be low during discharge (negative slope on the triangle wave).

The latest data sheet corrects the photograph Figure 7 on Page 5 of the data sheet. The 20% duty cycle square wave was inverted, i.e., should be 80% duty cycle. Also, on that page under "Waveform Timing" the related sentences should read "RA controls the rising portion of the triangle and sine-wave and the 1 state of the square wave." Also, "the falling portion of the triangle and sine wave and the 0 state of the square wave is:"

**Q11.** Under Parameter Test Conditions on Page 3 of your 8038 data sheet, the suggested value for min. and max. duty cycle adjust don't seem to work.

**A.** The positive charging current is determined by RA alone since the current from RB is switched off. (See 8038 Application Note A012 for complete circuit description.) The negative discharge current is the difference between the RA current and twice the RB

current. Therefore, changing RB will effect only the discharge time, while changing RA will effect both charge and discharge times. For short negative going pulses (greater than 50% duty cycle) we can lower the value of RB (e.g., RA = 50K $\Omega$  and RB = 1.6K $\Omega$ ). For short positive going pulses (duty cycles less than 50%) the limiting values are reached when the current in RA is twice that in RB (e.g., RB=50K $\Omega$  and RA = 25K $\Omega$ ). This has been corrected on the latest data sheet.

**Q12.** I need to switch the waveforms off and on. What's a good way to strobe the 8038?

**A.** With a dual supply voltage (e.g.,  $\pm 15V$ ) the external capacitor (pin 10) can be shorted to ground so that the sine wave and triangle wave always begin at a zero crossing point. Random switching has a 50/50 chance of starting on a positive or negative slope. A simple AND gate using pin 9 will allow the strobe to act only on one slope or the other, see Figure 2. Using only a single supply, the capacitor (pin 10) can be switched either to V+ or ground to force the comparator to set in either the charge or discharge mode. The disadvantage of this technique is that the beginning cycle of the next burst will be 30% longer than the normal cycle.

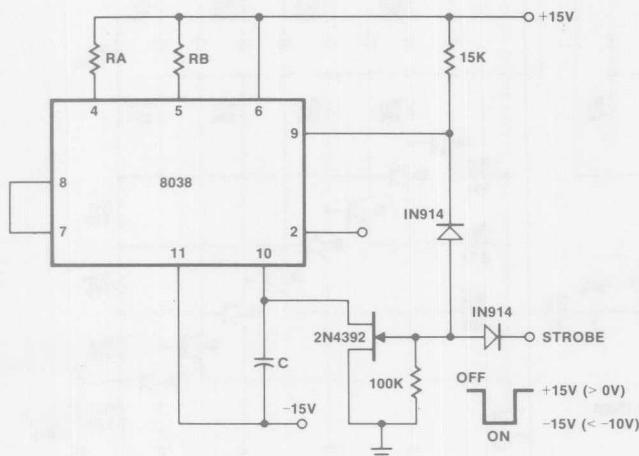


FIGURE 2. STROBE — TONE BURST GENERATOR

**Q13.** How can I buffer the sine wave output without loading it down?

**A.** The simplest circuit is a simple op amp follower as shown in Figure 3A. Another circuit shown in Figure 3B allows amplitude and offset controls without disturbing the 8038. Either circuit can be DC or AC coupled. For AC coupling the op amp non-inverting input must be returned to ground with a 100K $\Omega$  resistor.

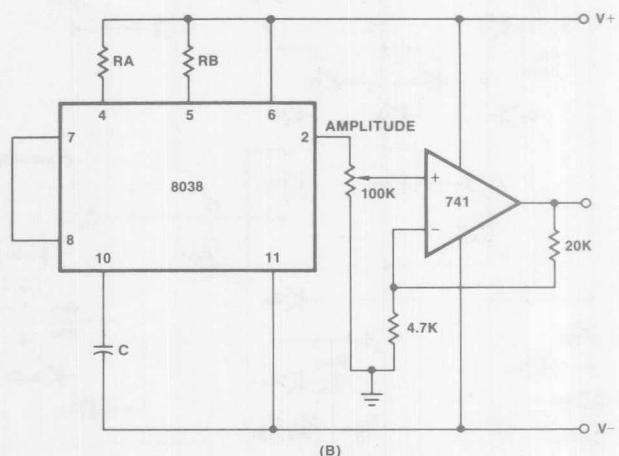
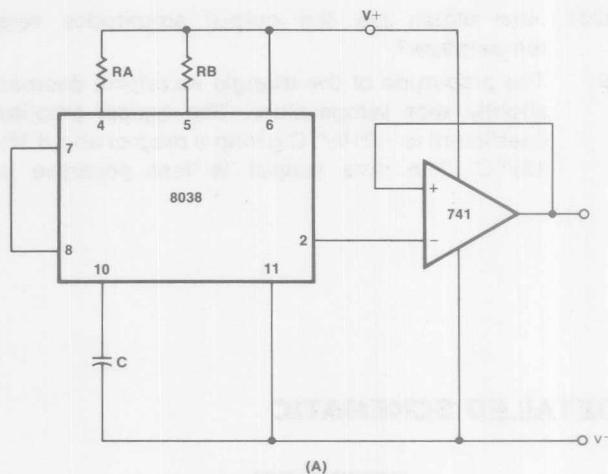


FIGURE 3. SINE WAVE OUTPUT BUFFER AMPLIFIERS

**Q14.** Your 8038 data sheet implies all waveforms can operate up to 1 Megahertz. Is this true?

**A.** Unfortunately, only the square wave output is useful at that frequency as can be seen from the curves on page 4 of the data sheet, distortion on the sine wave and linearity of the triangle wave fall off rapidly above two hundred kilohertz.

**Q15.** Is it normal for this device to run hot to the touch?

**A.** Yes. The 8038 is essentially resistive. The power dissipation is then  $\frac{E^2}{R}$  and at  $\pm 15$  volts the device does run hot. Extensive life testing under this operating condition and maximum ambient temperature has verified the reliability of this product. Copies of the reliability report are available from Intersil.

**Q16.** My data sheet shows a device with only 12 pins. The 8038 I received has 14 pins. How can I hook it up?

**A.** Our artist got lazy and decided to draw only the twelve pins that are used and omitted pins 13 and 14 which are not connected. The pin numbers and their functions are correct. This drawing has been corrected on the latest data sheet.

**Q17.** How stable are the output amplitudes versus temperature?

- A. The amplitude of the triangle waveform decreases slightly with temperature. The typical amplitude coefficient is  $-0.01\text{%/}^{\circ}\text{C}$  giving a drop of about 1% at  $125^{\circ}\text{C}$ . The sine output is less sensitive and

decreases only about 0.6% at  $125^{\circ}\text{C}$ . For the square wave output the  $V_{CE(\text{sat})}$  goes from 0.12V at room to 0.17 at  $125^{\circ}\text{C}$ . Leakage current in the "1" state is less than a few nanoamperes even at  $125^{\circ}\text{C}$  and is usually negligible.

## DETAILED SCHEMATIC

